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Technical Evaluation Report

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Introduction

The Fall 2001 Meeting of the Applied Vehicle Technology Panel (AVT) comprised two Symposia and one Specialists' Meeting on the subject of 'Life Management Techniques For Aging Air Vehicles'. This technical evaluation report addresses the above-mentioned Specialists' Meeting and reviews the papers, which have been presented in this meeting.

Objectives of the Specialists' Meeting

The programme for the Specialists' Meeting was structured into ten sessions covering the wide topic of aging air vehicle problems and in total thirty-one comprehensive papers were presented. Due to the non-availability of some authors and withdrawal of some papers on short notice the programme had to be continuously rearranged, but thanks to the effort by the Chairmen of the Specialists' Meeting Dr. J. W. Lincoln and Dr. M. Winstone the scheduled programme of the meeting could be performed.

The declared theme of the Specialists' Meeting was:

"The military commanders in all NATO countries are seeing their aircraft operate well beyond the time they originally intended to retire them. The cost of maintaining these aging aircraft are draining the existing budgets to the point that money will not be available to modernize their fleets when they will need to be retired because of obsolescence. A possible path to reduce this economic burden is through research and development. It is not always clear, however, what the best return will be when allocating funds for research and development for aging problems.

The specialists meeting will provide the attendees with guidance on strategies for the development and implementation of new and existing technologies, and logistic management processes. They will then be in a better position to prioritise resources for fleet management and fleet management research and development options. The emphasis will be on military aircraft, but many of the papers will be apply to land vehicles as well. The topics will cover the entire range of aging problems including avionics, mechanical subsystems, structures and wiring. There will be papers devoted to the role of information management as it applies to the aging problem. The forty-two papers on the agenda were written to address the needs of the manager charged with maintaining aging systems. The technical details will be minimised in favour of providing a broad overview of aging issues.

The papers are designed to provide the attendees with an understanding of safety and, economic implications of aging problems such as fatigue cracking, corrosion, wear and material degradation. In addition, the current status of technologies such as non-destructive inspection, repair, modifications, prevention analysis, and health management will be discussed. They will also describe the technology shortcomings for effectively addressing the aging problems and, where possible, the investment required for attaining the needed capability".

Session 1 – Overviews

This session consisted of three papers from the services covering the management aspects for aging aircraft fleets. The major challenges result from the facts that the average age of aircraft in service is increasing from year to year, that only small numbers of aircraft are replaced by new systems and that this results in reduced availability and reduced mission capability rates for the fleets and, therefore increased spending for maintenance action is required to overcome these problems. The papers highlighted that a management strategy is essential to overcome this "death spiral".

The US Air Force has established a Programme Office for Aging Aircraft and is pursuing an integrated approach from analysis of the problems to integration of appropriate solutions in the form of roadmaps. A Depot System Capability Plan has been established to address future needs. Technology projects and technology demonstrations for aging aircraft are selected on the basis of return of invest (ROI).

The experience of the Italian Air Force (IAF) is that management tools, e.g. life cycle cost control are an essential element. Fleet monitoring for aging aircraft has been established and big emphasis is given to move to condition based maintenance and pro-active maintenance rather than to remain at corrective maintenance actions.

The German Air Force has learnt that the established maintenance databases are by far not sufficient to cover the problems of aging aircraft. The general approach followed is to change from a safe life to a damage tolerance philosophy. The German Air Force aims to improve usage monitoring by integrated systems.

Session 2 – Avionics

Unfortunately only one paper covered the issues of avionics in aging aircraft; however, the problems of obsolescence of avionic components are addressed in numerous other lectures. The paper showed that obsolescence even occurs on relative new projects and that the military market, due the small volume and the long periods between upgrades is no longer the technology driver for electronics. Operational capability upgrades of aging systems with respect to software and hardware updates are required to achieve long-term supportability of in-service weapon systems.

Session 3 – Strategy for Structures and Subsystems

Three papers have been presented on that subject. The papers outlined the following problem areas with respect to structures: Fatigue cracking and corrosion in structures, onset of widespread fatigue damage, substitution of materials and repair of airframes, lack of adequate non-destructive evaluation techniques for corrosion damage and widespread fatigue detection. The subsystems are one of the largest contributors to unscheduled maintenance and in general the subsystems become more and more unsupportable due to obsolescence problems, and a prediction of the remaining life of subsystem components is almost impossible. The papers highlighted that inadequate databases are available to determine damage and failure modes and the sources of damage/failure. A lack of non-intrusive techniques to access wiring health was identified. On subsystems, which in most cases do not comprise safety critical items, it was felt extremely difficult to obtain investment in research and development, as the appropriate return of invest could hardly be justified.

In September 1997 the United States National Research Council published a report identifying forty-nine research and development activities in aging aircraft. A System Programme Office for Aging Aircraft has been formed in 2001. A deterministic approach for ASIP and MECSIP has been adopted and a stepped approach from survey of the problems to transition of technology into aging systems is pursued. Research and

development of technology has been initiated to assure safe and economic operation of military aircraft. The Air Logistic Centre has opted for the Functional Systems Integrity Programme (FSIP) in order to reduce availability problems.

Session 4 – Corrosion Management

This session was again covered by three papers, which showed the approaches in Australia, Italy and Canada. The papers addressed the different problems associated with corrosion management like impact of corrosion on airworthiness and flight safety, and readiness and efficiency of the fleet. A huge economic burden by corrosion was recognised in a "fix when found" maintenance environment, and a move to "assess and manage" corrosion problems should rather be adopted in future. The discovery of "fleet-threatening" corrosion has been identified as a major challenge. With respect to non-destructive inspection methods the suitability of NDI methods to detect corrosion in an early state and the probability of detection, respectively the detection of corrosion in different layers, in thick parts and in joints have been identified as areas where further research and development is required. In addition, to obtain deeper insight into the corrosion problem, appropriate modelling of the impact of corrosion on airworthiness and a dedicated monitoring of in-service corrosion data has to be established.

Australia has adopted the approach to incorporate corrosion into the Aircraft Structural Integrity Management Plans (ASIMP's) and to evaluate structural degradation management with important crossover of fatigue and corrosion effects. Emphasis is given to the analytical prediction of remaining life with exfoliation and pitting, and in maintenance procedures by the application of suitable corrosion preventives on aging aircraft.

In Italy a Corrosion Control Register Programme (CCR) has been established since six years, originally for the TORNADO aircraft, but in the meantime this CCR has been extended to six more aircraft. Indices for corrosion at different operational levels are applied down to part level. For the classification of corrosion damages four different classes have been selected.

Canada, in collaboration with USAF, has advocated a strict corrosion management approach. The Holistic Life Prediction Methodology (HPLM) includes environmental as well as fatigue mechanisms. The aim is to implement a HPLM based pro-active maintenance philosophy.

Session 5 – Modifications, Repairs, Analysis, and Life Extension

Due to the withdrawal of one paper from Germany three papers from the United States covered this session. The challenges with respect to aging aircraft addressed the changes in operational environment and incorporation of new stores, respectively role configurations, and the damaging environment, which could not be properly considered in the original design. Additionally major problems are found with regard to the life enhancement of airframe holes and the repair of holes and bushings, to fatigue cracks in structures requiring structural replacement and to the effects of widespread fatigue damage on residual strength. The economics of ongoing inspections, the correlation of analytical and test results and the complexity of joints has been addressed. For future modifications and repairs the application of new materials and fabrication methods, like the use of castings, should to be considered.

The papers presented different approaches to overcome the problems associated with repair and modifications. First, the application of the cold expansion process for holes and bushings for aging aircraft and new designs represents a low cost method to increase airworthiness by arresting the growth of small undetected cracks. Another cost-effective solution is the application of damped bonded patches into retrofit and repair actions, as a

repair time of less than twenty-four hours could be achieved with room temperature curing adhesives. In addition it was recommended to develop a methodology for widespread fatigue to improve the correlation between actual test results and analytical methods.

Session 6 – Engines

The subject of aging engines was covered by four papers from the United Kingdom, from Canada, from Poland and from the United States. The challenges generally presented are the cost-effective management of engines, aging engine problems due to obsolescence, and the safe operation of engines at maximum life beyond the service life. A more detailed understanding of deterioration modes and the potential impact on engine performance, reliability and safety is required. An improvement of non-destructive inspection methods and a higher probability of detection of defects have to be achieved, and, based on the failure history, a validation of the inspection technologies has to be pursued.

The papers presented the incorporation of modern Health and Usage Monitoring System (HUMS), and with respect to maintenance actions the repair of components respectively substitution of materials to extend engine components lives. The use of innovative living techniques, and the use of databases to analyse the different operational phases have been proposed to cope with aging engine components, and, in addition a risk management methodology should be established to address the problems of aging engines.

Session 7 – Wiring and Electrical

Three papers addressed the problem areas of aging wiring and electrics. The deterioration of physical properties and the performance with time, the handling of electrical wiring, the environment, the usage, and in general installation and maintenance practices were identified as major sources for repair action. Conductors and connectors contribute to approximately forty-five percent of the failures and therefore have a significant impact on maintenance cost. The available diagnostic tools are considered not comprehensive to locate damage. Wiring problems are usually found by troubleshooting rather than by visual inspection. Therefore a change from reactive to pro-active maintenance is required, as in older aircraft the risk due to wiring problems and arcing in circuit breakers is continuously increasing.

The solutions to this problems presented in the different papers addressed the requirements for additional wiring inspection with necessary portable inspection equipment to be developed, the identification of corrective action/repair and the urgent necessity for additional repair tools, techniques and materials. With respect to the electrical failures occurring in service appropriate databases for wiring codes and wiring systems have to be established, and wiring and electrical failure data/results need to be recorded and stored in these databases. In addition fault graph methodologies need to be established.

Session 8 – Non-Destructive Inspection

The two papers presented in this session discussed the pivotal role of non-destructive inspection for maintaining safety through early crack detection and for minimising corrosion maintenance cost. Corrosion becomes a significant driver for airframe maintenance planning with an high economic impact. Assessment methodologies for corrosion with appropriate probabilities of inspection have to be established. A major challenge exists in finding hidden corrosion economically and work should be focussed of those areas with high return of invest.

Further research is needed in modelling and metrics of corrosion in lap joints and thick sections, and to obtain decision guidelines whether to repair or not to repair parts affected by corrosion. More extensive use of automated inspection equipment to detect corrosion has to be considered in order to reduce the inspection burden.

Session 9 – Information Management

This session was covered by two papers from the United States. For aging fleets the tools and technologies to support obsolescence problems are required. In general the prediction of useful remaining life is a problem and a lack of information to identify and quantify the risks has been identified, especially as maintenance data are not consistently recorded and sometimes stored on different databases, which does not allow the fusion of the failure data. This information is considered essential for the change from a diagnostic to a prognostic maintenance approach. Current state of the art technologies, like health and usage monitoring systems need to be transitioned into aging systems to reduce the high cost of maintenance.

To overcome the problems with aging aircraft data gathering with new sensors has to be improved, and the fusion of available databases, together with the incorporation of expert knowledge has to occur. An extensive modelling of aging aircraft systems, together with an improvement of damage mechanism prediction, has to be initiated to determine when sustainment actions have to be performed. The available databases need to be established on a much broader base, e.g. on NATO level to collect the experience in the different services. Last not least the mental change from diagnostic to prognostic maintenance action has to be achieved.

Session 10 – Fleet Management

In the management of aging fleets the high standards of safety still have to be achieved, even when the supportability of in-service weapon systems is jeopardized by obsolescence and associated with continuously increasing maintenance cost. The DSTO and the Australian Air Force have addressed the special case of being the sole operator of F-111 aircraft.

As possible solutions to reduce the problems in fleet management the use and adaptation of state of the art technologies for modifications, repairs and part re-manufacture and additional investment in these areas to transfer available technologies, like health monitoring, repair actions and advanced corrosion treatments, to aging aircraft were presented. A necessity for better tools and simulation to forecast life cycle cost of aging fleets and to determine the economic service life has been identified. Within the modelling, methodologies to take into account corrosion, fatigue damage and widespread corrosion have to be developed to support a structural management approach for aging aircraft fleets. Extensive databases with historical data and fusion of these data are considered as key element to make this approach a success.

Concluding Remarks

As already expressed in the objectives of the specialists' meeting most papers addressed aging issues and the associated economic burden on military aircraft, and the further research and development work required. However, other vehicles, like land vehicles, could benefit substantially from the lessons learnt and the technologies incorporated in air vehicles, assuming that an exchange of information could be arranged.

Within the objectives of the specialists' meeting the papers presented were of very high quality and the content of the papers were in almost all cases highlighting the overall problems rather than to present too much technical detail. The necessary research and development issues were clearly identified and it is recommended that these issues are

pursued by the services in order to improve the availability of aircraft in service and to reduce the high costs associated with aging aircraft maintenance.

It is recognised, that research and development funding can be more easily obtained for "new and advanced projects" than for research on existing and old aircraft and that it is sometimes hard to justify the return of invest of these research investments. However, as the available fleets become increasingly older from year to year and only small numbers of the existing fleet are replaced by new aircraft, basically a "mental" change is required with respect to aging aircraft problems. Due to the changing threat scenarios since the beginning of the 90's and the associated reduced defence budgets more aging aircraft will continue to be in service for even longer periods.

The specialists' meeting has shown, that state of the art technologies are available, which could be incorporated into aging air vehicles and that, in a lot of areas, adaptation of these new technologies to aging vehicles could be achieved by additional research activity. The research areas identified should be pursued in order to reduce maintenance cost.

It is the opinion of the author that current R&D regulations, according to which research and development spending can be obtained only in the initial phases of new projects, should be reviewed with respect to their rationale. The necessity to adapt and transfer existing technologies to aging fleets is without question and the areas where further research activities are required have been highlighted at the specialists' meeting. The services should take advantage of these possibilities to keep their fleets operational respectively and provide appropriate funding for research and development on aging air vehicles.

To RTO it is recommended that the subject and the problems associated with aging air vehicles should be pursued on a NATO wide basis and that RTO continues to support the activities on aging vehicles in the future.